

# ***The Navy's Lithium Battery Safety Program***



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NSWC Crane***





# ***Lithium Battery Safety Program***

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## **Outline of Presentation**

- **Introduction and Background on Lithium Batteries**
- **History of the Lithium Battery Safety Program (LBSP)**
- **Process for Lithium Battery Safety Approval**
- **LBSP and WSESRB Relationship**
- **Conclusion and Questions**





# Lithium Battery Safety Program

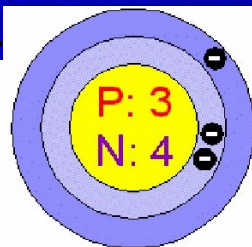
## Lithium Facts:

- Element with Atomic Number 3
- Lightest Alkali Metal ( $\rho=0.53 \text{ g/cm}^3$ )
- Silvery, Metallic Solid at Room Temp
- Very High Thermal and Electrical Conductivity
- Highest Specific Heat of any Solid Element
- Source - Salts & Hydrates
- Melts at 180.5 C (357.0 F)
- Reacts with Water
- Burns in Air
- Very High Electrochemical Potential
- Extremely Mobile +1 Ions

### ALKALI METALS

Lithium  
Sodium  
Potassium  
Rubidium  
Cesium  
Francium

ates



P: 3  
N: 4

**6.94**  
**Atomic**  
**Weight**

H	He																	He
Li	Be																	Ne
Na	Mg																	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub							
			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	





# ***Lithium Battery Safety Program***

## **Lithium Uses and Applications**



### **NON-ENERGETIC:**

- **Lithium Citrate Used in the Original 7-Up Soda (Original Name, ~1929, was “Bib-Label Lithiated Lemon-Lime Soda”)**
- **Lithium Carbonate Used As Anti-Depressant Drug**
- **Lithium Compounds Used in the Production of Aluminum from Oxides (Enhances conductivity for electrolysis of  $\text{Al}_2\text{O}_3$ )**
- **Li-Al Alloys Used in Lightweight Structural Applications (Aircraft)**
- **Lithium Oxides and Fluorides Used in Glasses and Ceramics (Mt. Palomar Telescope)**





# ***Lithium Battery Safety Program***

## **Lithium Uses and Applications (cont.)**

### **ENERGETIC:**

- **Lithium Metal Used As a Heat-transfer Medium**
- **Lithium Metal Used Directly As a Fuel (Mk 50 Propulsion)**
- **Lithium Metal (and Alloys) Used As Battery Anode Material**
- **Other Emerging Technologies - Lithium Perchlorate Oxygen Storage, Lithium Semi-cell Fuel Cells, etc.**





# ***Lithium Battery Safety Program***

**Q. *What is a lithium battery?***

**A. One or more electrochemical cells (containing lithium as a metal, alloy or compound) electrically connected in an appropriate series/parallel arrangement to provide the required operating voltage and current levels including, if any, monitors controls and other ancillary components (fuses, diodes), case terminals and markings**

Linden & Reddy, Handbook of Batteries, Third Edition

**A. A self-contained chemical reactor (containing lithium as a metal, alloy or compound) that is capable of transforming chemical energy into electrical energy on demand**

Levy & Bro, Battery Hazards and Accident Prevention





# ***Lithium Battery Safety Program***

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## **Lithium Cell Types Used by the Navy**

- **Primary (Non-rechargeable)**
  - **Active**
  - **Reserve**
    - **Liquid electrolyte**
    - **Thermal**
- **Secondary (Rechargeable)**





# ***Lithium Battery Safety Program***

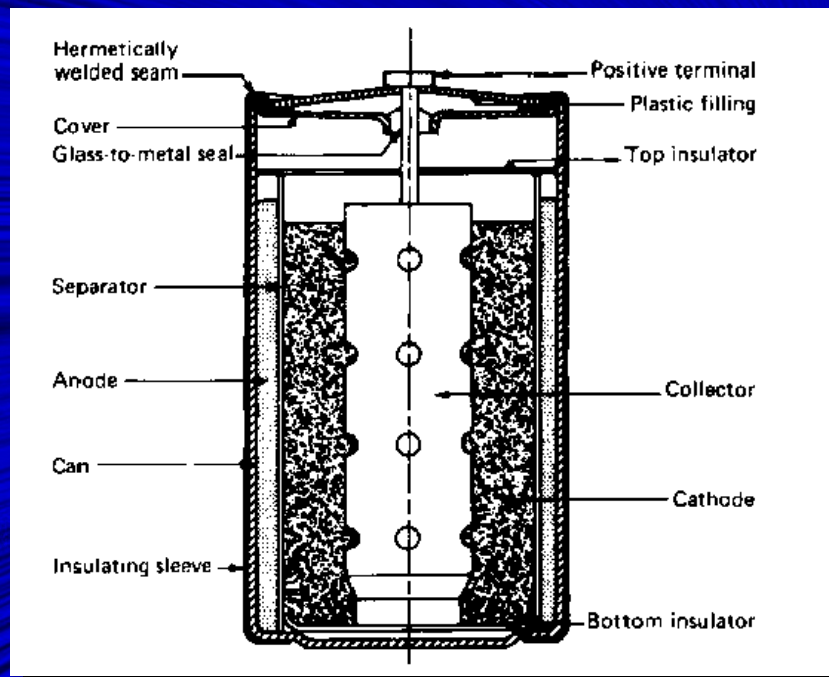
## **Lithium Cell Chemistries Used by the Navy**

- **Solid Cathode --  $\text{Li/MnO}_2$ ,  $\text{Li/CF}_x$ ,  $\text{Li/FeS}_2$ ,  $\text{Li/V}_2\text{O}_5$**
- **Liquid Cathode --  $\text{Li/SOCl}_2$ ,  $\text{Li/SO}_2$ ,  $\text{Li/SO}_2\text{Cl}_2$**
- **Lithium metal anode**
- **Lithium alloy anode**
- **Lithium ion anode**

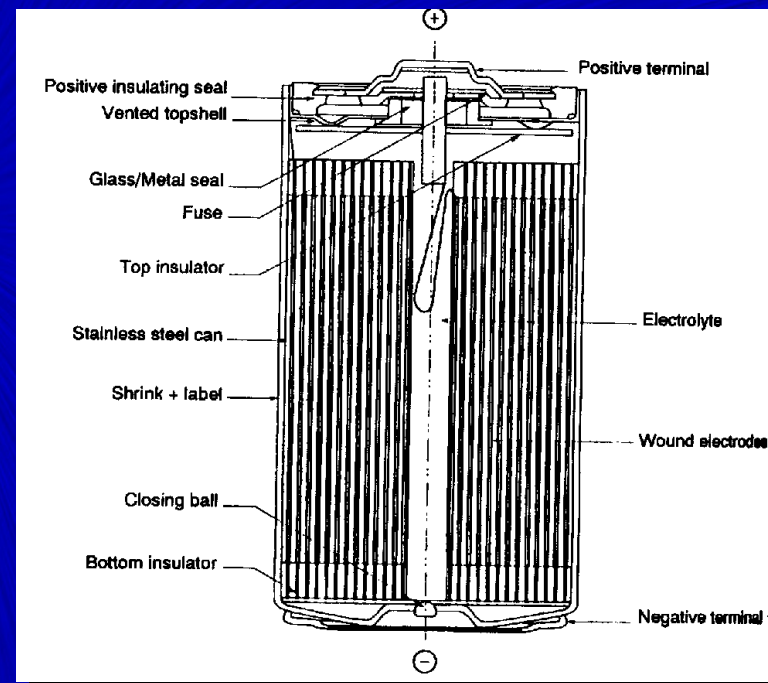


# Lithium Battery Safety Program

## Lithium Cell Designs Used by the Navy



**Bobbin**



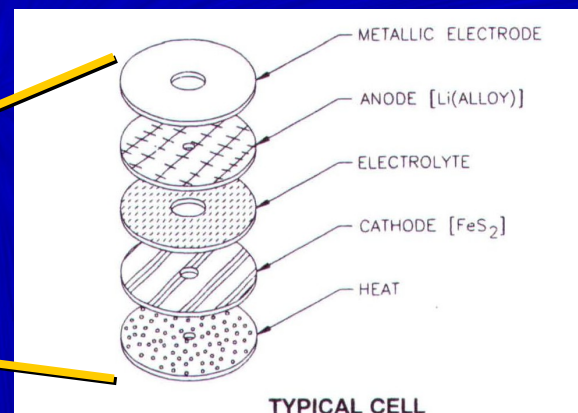
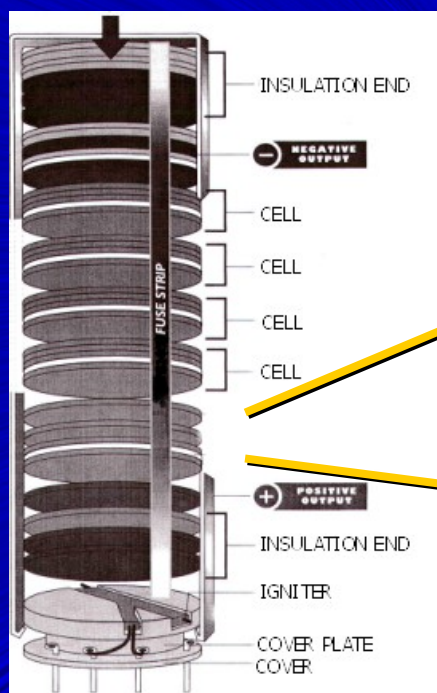
**Spiral Wound**





# Lithium Battery Safety Program

## Lithium Cell Designs Used by the Navy



**Bipolar Stacked**

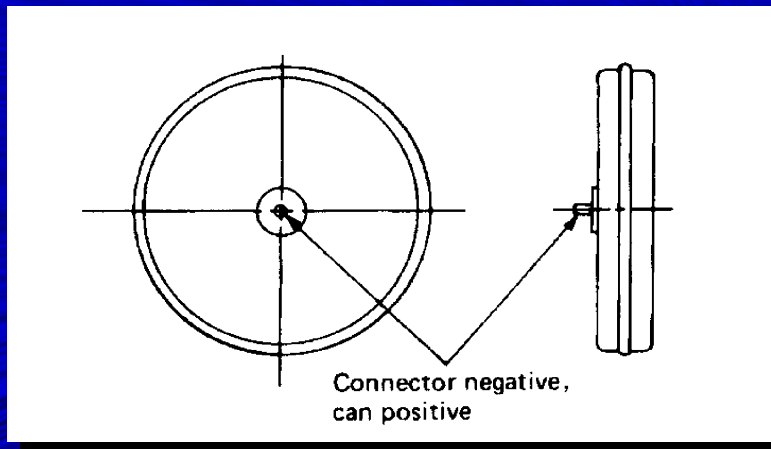
ASB-MSB Thermal Batteries Guide/EPT Technician



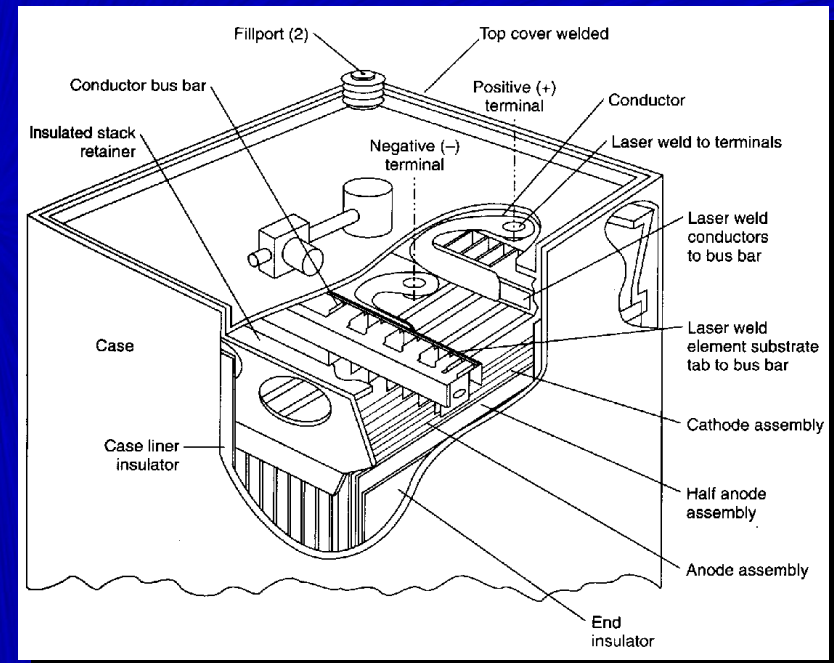


# Lithium Battery Safety Program

## Lithium Cell Designs Used by the Navy



**Coin**



**Prismatic**

Linden & Reddy, Handbook of Batteries, Third Edition





# ***Lithium Battery Safety Program***

## **Lithium Cell Sizes**

- **Button cell (0.01 Ah)**
- **2/3 AA (0.60 Ah)**
- **1/2 AA (0.95 Ah)**
- **2/3 A (1.20 Ah)**
- **AA (1.90 Ah)**
- **A (2.8 Ah)**
- **9V (1.20 Ah)**
- **1/3 C (0.86 Ah)**
- **2/5 C (2.50 Ah)**
- **C (5.4 Ah)**
- **D (7.2 Ah)**
- **DD (16.5 Ah)**
- **Specialty design cell (2,200 Ah)**
- **10,000 Ah prismatic cell**





# ***Lithium Battery Safety Program***

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## **Where Lithium Batteries Are Used in the Navy**

- **Communication Radios**
- **Mine Countermeasures Decoys**
- **Locator Beacons**
- **Memory Back-Up**
- **Emergency Signal Devices**
- **Missile Guidance & Control**
- **Laser Detection Devices Propulsion**
- **Night Vision Goggles**
- **Mines**
- **Electronic & Acoustic**
- **Sonobuoys**
- **Deep Ocean Sensors**
  - **Transponders**
  - **Telemetry Systems**
  - **Small UUV**
- **Laptop Computers**





# ***Lithium Battery Safety Program***

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## **Common Safety Devices for Lithium Batteries Include:**

- **Electrical fuses**
- **Thermal fuses**
- **Diodes (charging and bypass)**
- **Voltage monitors**
- **FETs**
- **Vent structures**
- **Fuseable separators**





# ***Lithium Battery Safety Program***

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**Lithium Battery = Stored Chemical Energy**

- **Controlled release of this energy provides electrical power in the form of current and voltage**
- **Uncontrolled release of this energy can result in fire, exposure of toxic materials, shrapnel, high pressure events, and any combination thereof**





# ***Lithium Battery Safety Program***

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## **Origin of the Navy's Lithium Battery Safety Program**

- **First marketed in early 1970, primarily for military applications**
- **Featured substantial increases in both gravimetric and volumetric energy density**
- **Commercial and military facilities explored safety characteristics in the lab in conjunction with fielding systems**
- **Seven personal injuries were reported during the period 1976 through 1983, including one death**





## ***Lithium Battery Safety Program***

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- **NAVSEAINST 9310.1A of 11 March 1982**
- **NAVSEANOTE 9310 of 11 June 1985**
- **NAVSEAINST 9310.1B of 13 June 1991**
- **Technical Manual for Batteries, Navy  
Lithium Safety Program And Procedures  
S9310-AQ-SAF-010 of 20 July 1988**





# ***Lithium Battery Safety Program***

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## **S9310-AQ-SAF-010**

- **Introduction**
- **Selection and review**
- **Design**
- **Use**
- **Packaging**
- **Storage**
- **Transportation**
- **Disposal**
- **Emergency response procedures**
- **Safety and performance tests for certification**
- **Pass fail criteria**
- **Safety**





# ***Lithium Battery Safety Program***

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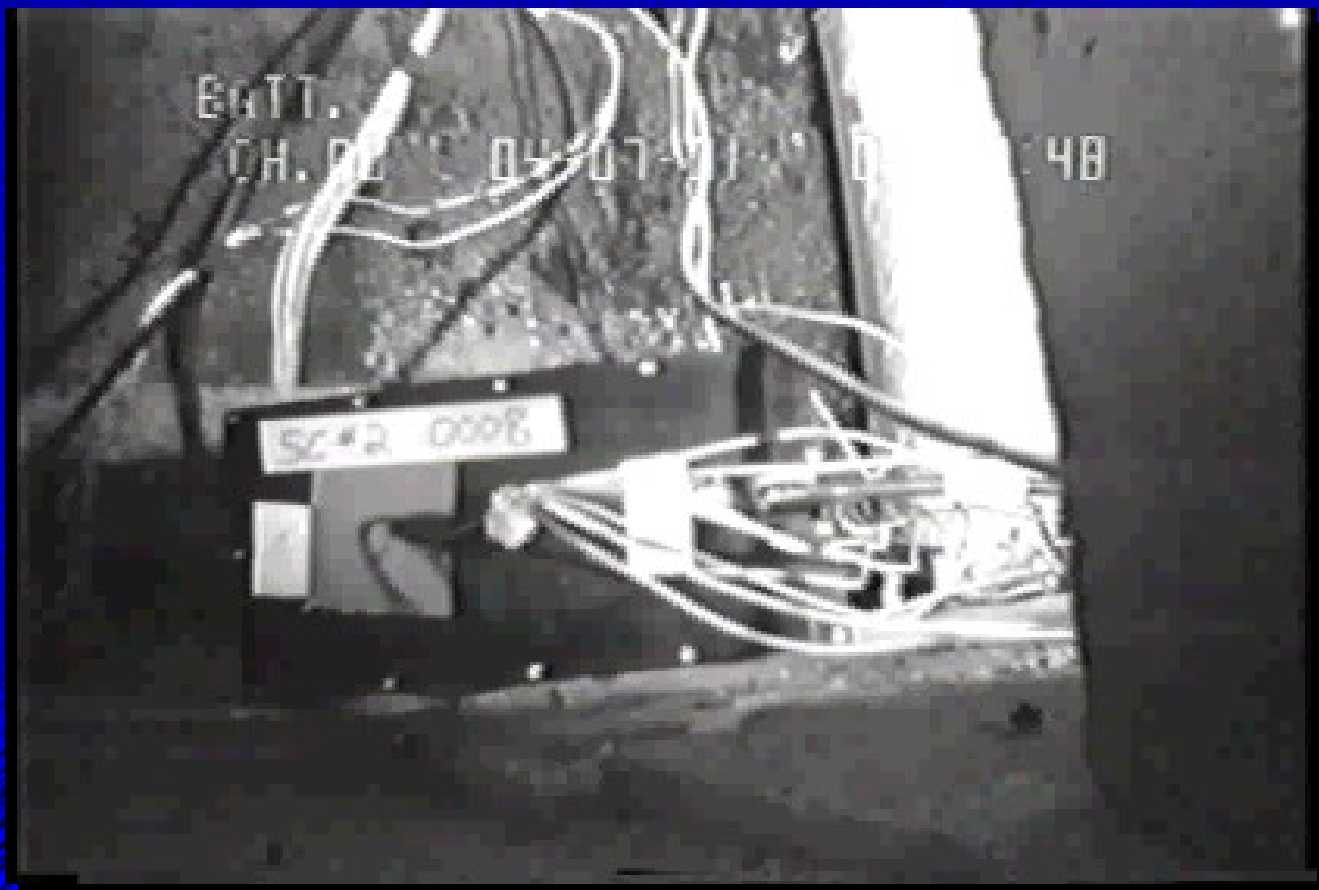
## **SAFETY TESTING (Primary Batteries)**

- **Constant current discharge & reversal**
- **Short circuit**
- **High temperature**
- **Charging**
- **Electrical safety device**





# ***Lithium Battery Safety Program***







# ***Lithium Battery Safety Program***

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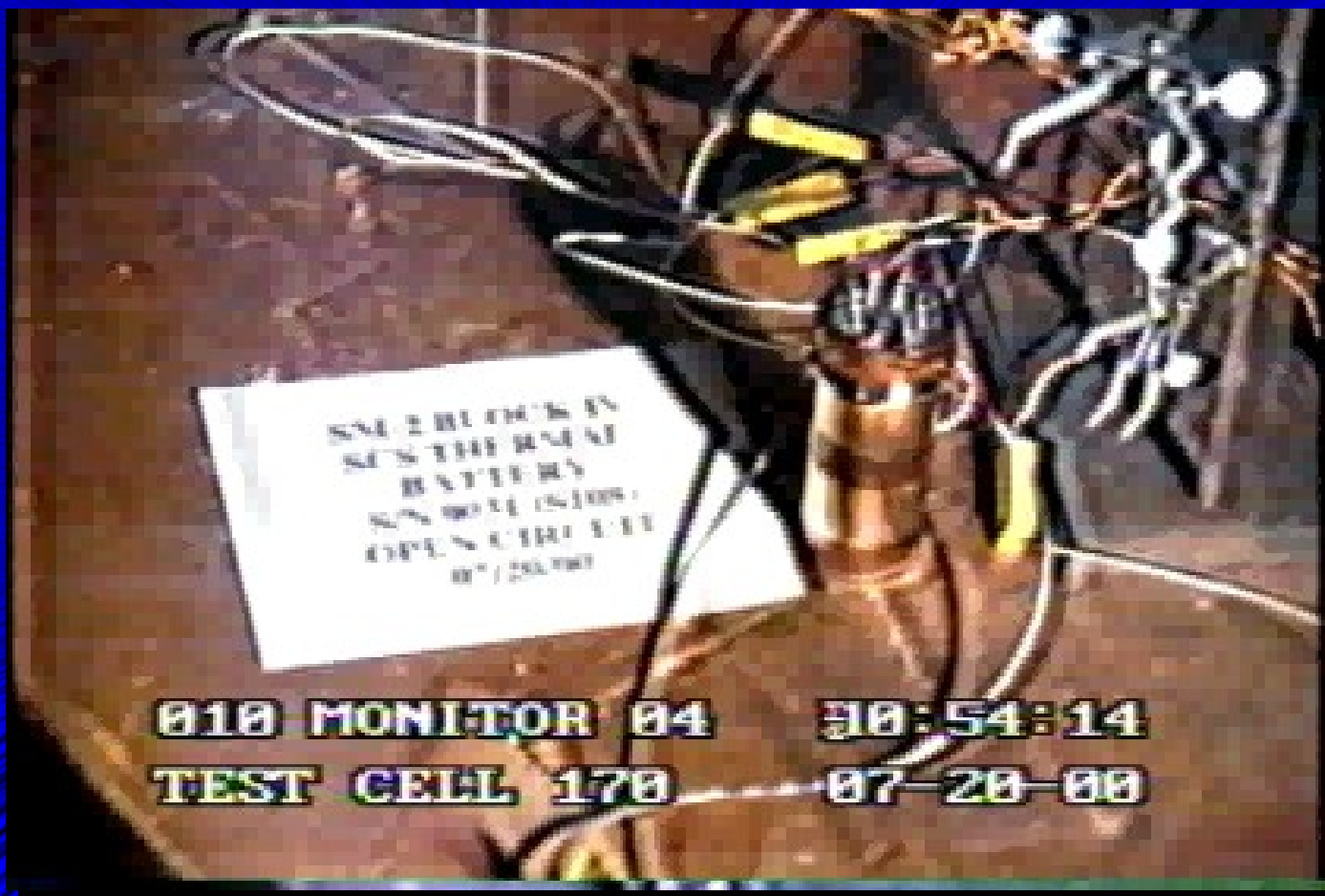
## **SAFETY TESTING (Thermal Batteries)**

- **Unactivated: Environmental**
- **Activated**
  - **High Rate Discharge**
  - **Thermal Abuse**
  - **Open Circuit**
  - **Charging**





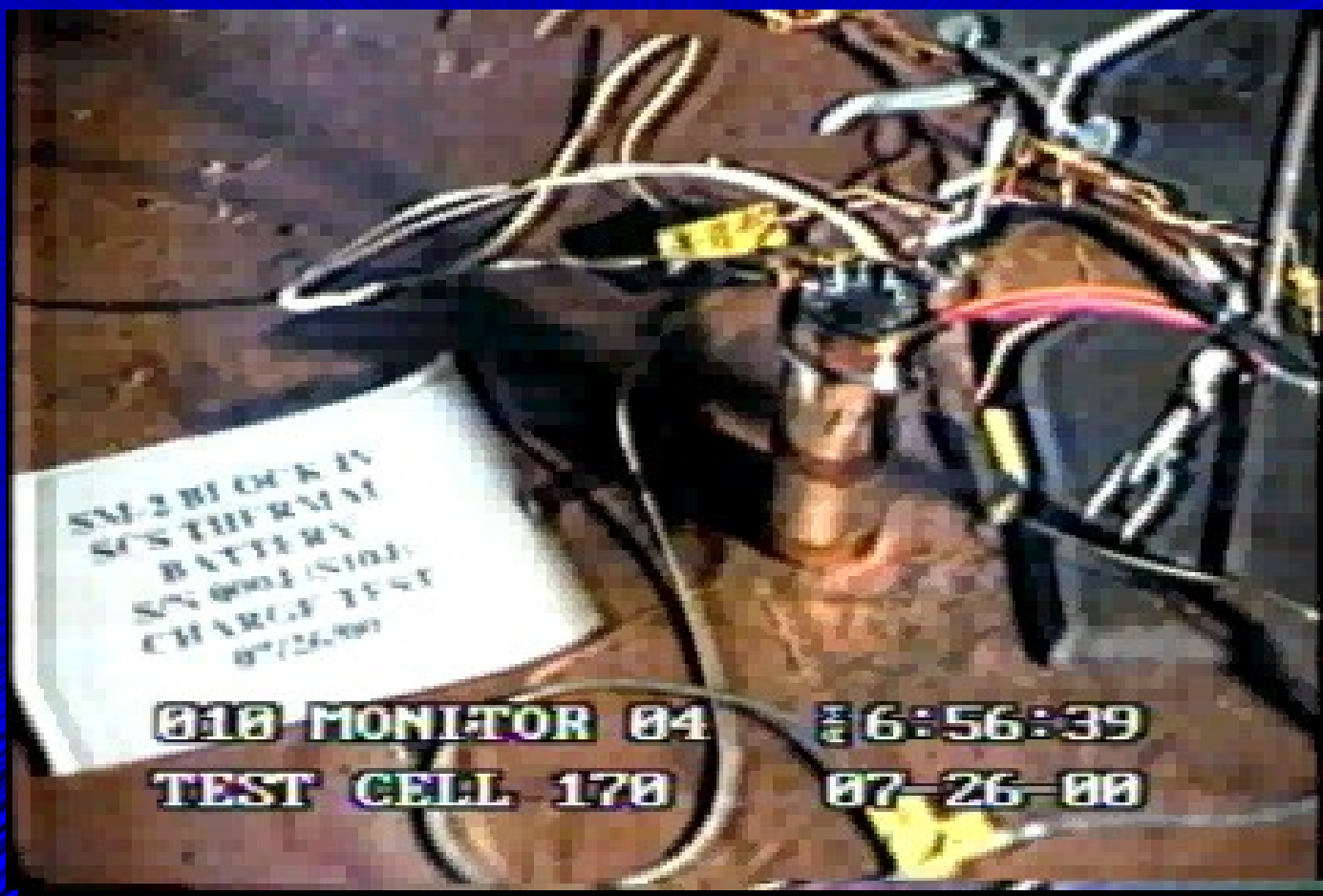
# *Lithium Battery Safety Program*







# *Lithium Battery Safety Program*







# ***Lithium Battery Safety Program***

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## **SAFETY TESTING (Reserve Batteries)**

- **Unactivated**
  - **Environmental**
  - **High Temperature**
- **Activated**
  - **Constant Current Discharge and Reversal**
  - **Short Circuit**
  - **Open Circuit**
  - **High Temperature Activation**





# ***Lithium Battery Safety Program***

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## **SAFETY TESTING (Rechargeable Batteries)**

- **Short Circuit**
- **Overcharge/Discharge**
- **Overdischarge/Charge**
- **High Temperature**
- **Electrical Safety Device**





# ***Lithium Battery Safety Program***

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# ***Lithium Battery Safety Program***

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## **REQUIREMENTS FOR APPROVAL**

- **Request letter**
- **Safety data package**
- **Test report**
- **Safety evaluation letter**
- **Draft approval letter**





# ***Lithium Battery Safety Program***

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## **REQUEST LETTER**

- **Defines**
  - **System**
  - **Platform**
  - **Action desired**
- **Submitted on letter head**
- **Signed**





# ***Lithium Battery Safety Program***

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## **SAFETY DATA PACKAGE**

- **Battery/Cell Description**
  - **Battery manufacturer**
  - **Model Number and/or Part Number**
  - **Electrical description**
  - **Operating life**
  - **Physical dimensions and description**
  - **Marking indicating battery chemistry**
  - **Cell and/or battery yield pressure**
  - **Material Safety Data Sheets**
  - **Cell failure mode**





# ***Lithium Battery Safety Program***

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## **SAFETY DATA PACKAGE (CONT.)**

- **Lithium battery-powered equipment description**
  - **Manufacturer**
  - **Model number and/or Part Number and device name**
  - **Diagram of the system's overall mechanical interfaces**
  - **Battery housing/container, strength, and free volume**
  - **Battery installation**
  - **Safety features or venting mechanisms**
  - **Current drain**
  - **Block diagram of system**
  - **Electrical schematic**





# ***Lithium Battery Safety Program***

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## **SAFETY DATA PACKAGE (CONT.)**

- **Logistics**
  - **Logistics and operational use**
  - **Packaging**
  - **Storage facilities**
  - **Transportation methods**
  - **Disposal information**
  - **Battery changeout replacement plan**
- **Functional, environmental and safety tests performed to date**
- **Proposed safety testing program plan**





# ***Lithium Battery Safety Program***

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## **PASS-FAIL CRITERIA**

- **An inability of the lithium batteries or lithium battery-powered equipment to meet the "*passing*" criteria does not necessarily result in an automatic rejection of the equipment for service use.**





# ***Lithium Battery Safety Program***

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## **UNIT CRITERIA**

- ***Land:*** Unit has a fail safe vent system to keep pressure below 50 percent of the yield pressure of the unit.
- ***Surface Ship:*** Same as above, except no external fire or flame.
- ***Aircraft:*** Same as above, except the use of liquid cathode lithium cells and batteries is strongly discouraged.
- ***Submarine:*** Total containment. Internal pressure shall stay below 50 percent of the yield pressure of the battery compartment.





# ***Lithium Battery Safety Program***

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## **UNIT CRITERIA (Cont.)**

- **Relief Mechanism Criteria**
  - **If pressure relief mechanisms are provided in the unit, they must prevent the pressure from reaching a peak value of 50% of the yield pressure of the unit.**
  - **If pressure relief mechanisms are not provided, the recorded peak pressure in any test must not exceed 50% of the yield pressure of the unit to be considered safe.**





# ***Lithium Battery Safety Program***

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## **UNIT CRITERIA (Cont.)**

- **Batteries must not vent in response to the Electrical Safety Device Test**
- **Reaction from the battery shall not adversely affect the safety of the unit**





# ***Lithium Battery Safety Program***

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## **SAFETY EVALUATION LETTER**

- **Contains the results of the review of the data submitted**
  - Request letter
  - Safety data package
  - Test report
  - Any other related information
- **Provides justification for recommendation for approval based on technical evaluation of all test and design data**
- **Restrictions and limitations**





# ***Lithium Battery Safety Program***

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## **APPROVAL LETTER**

- **Issued from NOSSA**
- **States conditions and limitations for use**





# ***Lithium Battery Safety Program***

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## **TIME TABLE**

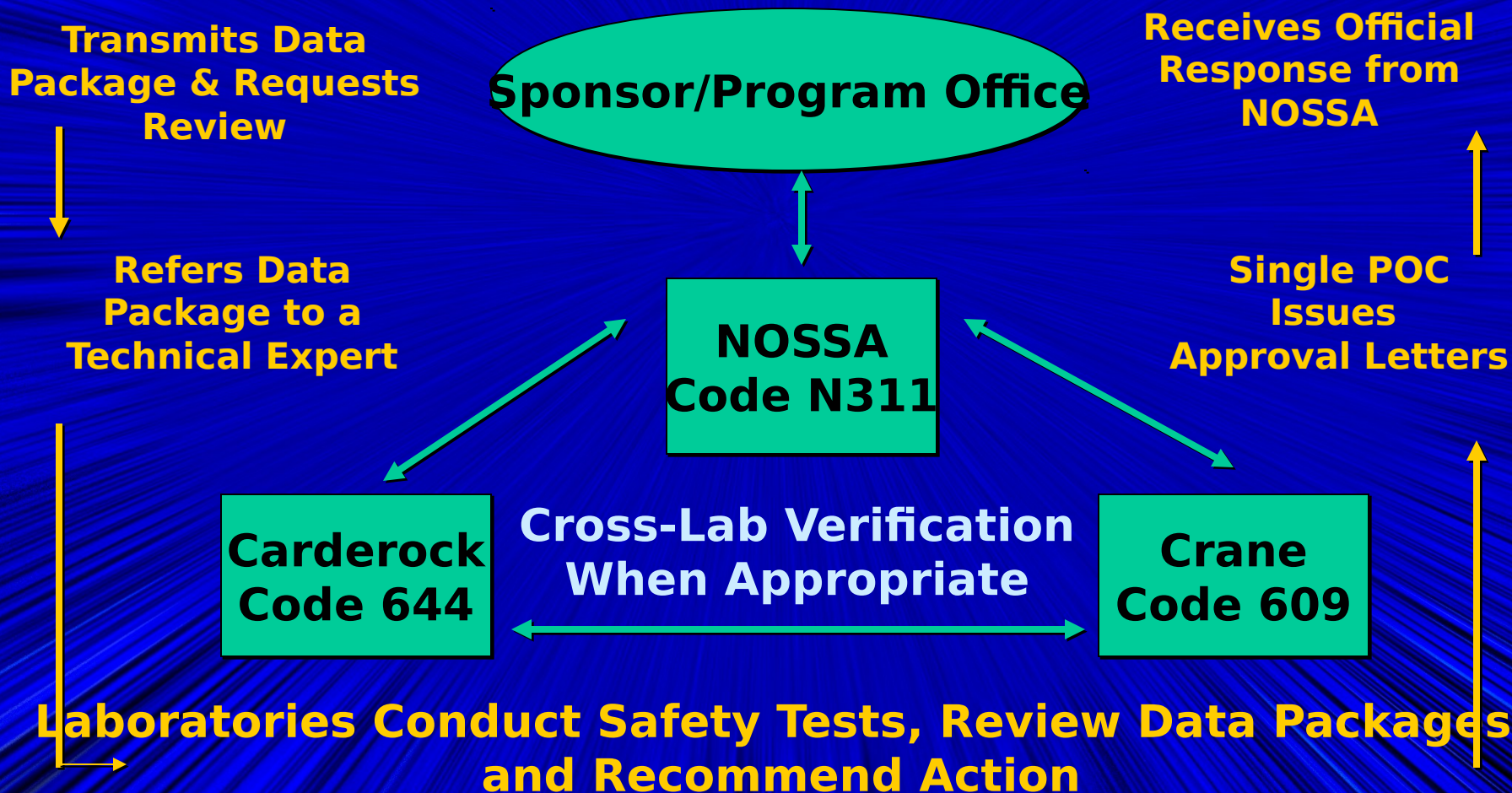
- **Three weeks to two months after receipt of all information**





# *Lithium Battery Safety Program*

## Lithium Battery Safety Program Tasking







# ***Lithium Battery Safety Program***

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## **Impacts of Lithium Battery Safety Program**

- **Lithium battery database**
- **Single POC for battery-related inquiries**
- **Design changes**
  - **Alternate non-lithium power sources**
  - **Added safety devices**
  - **Revised battery designs**





# ***Lithium Battery Safety Program***

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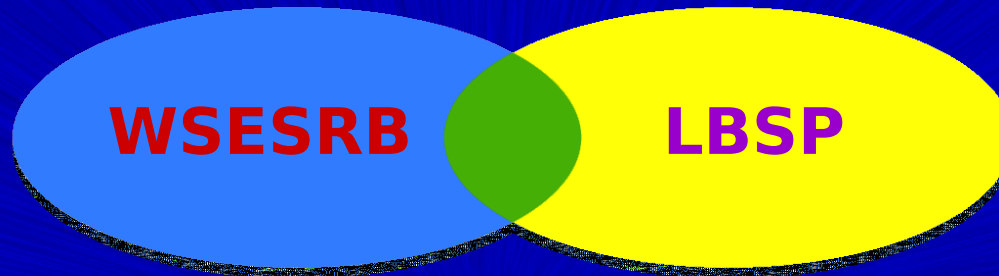
## **Relationship to WSESRB**

- **LBSP supports WSESRB charter by providing a source of data for hazard assessments on systems that include lithium batteries**
- **LBSP is independent of WSESRB because many applications that include lithium batteries are not subject to WSESRB review**
- **LBSP is similar in function to the SSSTRP and FISTRP**





# ***Lithium Battery Safety Program***



<b>WSESRB Only</b>	<b>Both</b>	<b>LBSP Only</b>
<b>Aegis</b>	<b>AFD</b>	<b>Reconnaissance UUVs</b>
<b>Nimitz</b>	<b>Artillery Fuzes w/batteries</b>	<b>CSEL Radio</b>
<b>JSHIP</b>	<b>Missile Systems</b>	<b>Integrated Navigation Sonar Sensor</b>
<b>2.75 Rocket System</b>	<b>LMRS</b>	<b>Army/USMC Comm Devices</b>
<b>BFTT</b>	<b>Torpedoes</b>	<b>Expendable Mobile ASW Training Target</b>
<b>Anti Tank Weapon</b>	<b>Countermeasure UUVs</b>	<b>Versatile Exercise Mine</b>





# ***Lithium Battery Safety Program***

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## **Conclusion**

**The concept of a lithium battery encompasses a wide variety of specific characteristics**

**The Navy has an excellent safety record with lithium battery use, and this is the process by which we have met and will continue to maintain this record**

**LBSPs primary function is to minimize risk to personnel and platforms while allowing the use of lithium batteries to advance our military capabilities**





# ***Lithium Battery Safety Program***

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